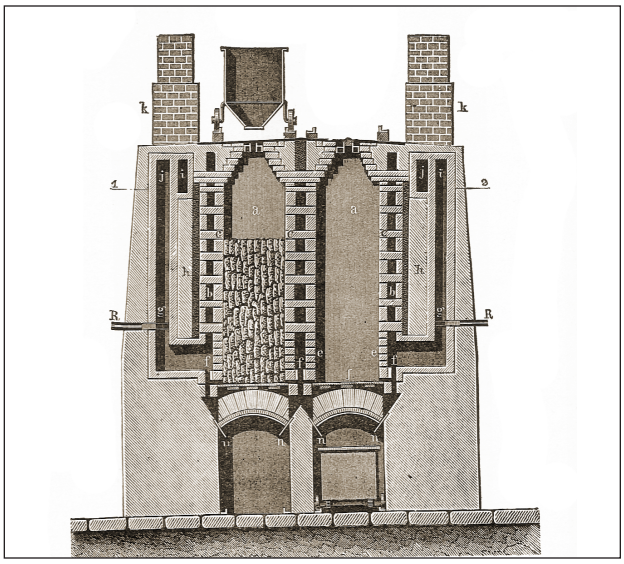
Darby's Coke Furnace

Iron-maker Abraham Darby built a furnace that used **coke** (coal from which the smoke-producing elements are baked out) to melt iron, so it could be cast in molds to make tools (cast iron).



Coke oven

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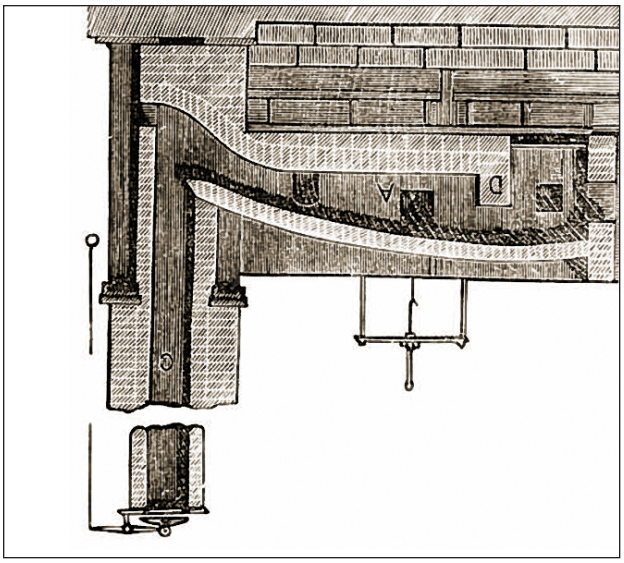
Cort's Puddling Furnace

Iron-maker Henry Cort patented the **puddling furnace**, which created pure iron. The iron-maker rolled the iron into strong forms (wrought iron), like railroad tracks, instead of being cast in molds.



Puddling furnace

A Few Facts

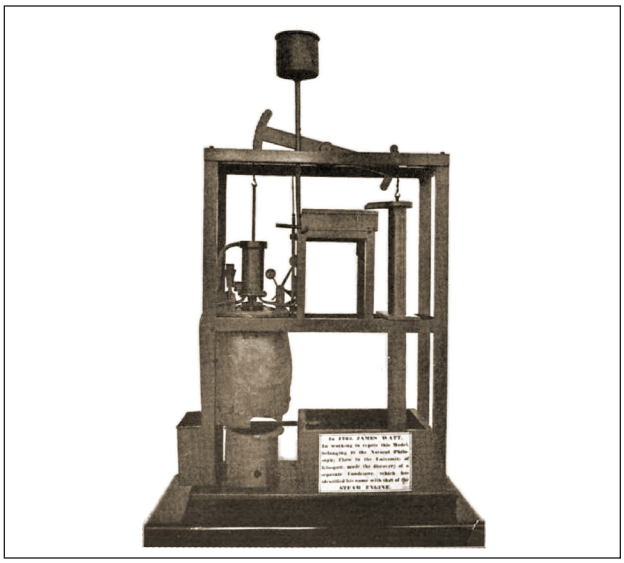
- In the 17th century, wood charcoal was the leading fuel for stoking (feeding) the furnaces used to smelt iron.
- Charcoal comes from the hardwood of old trees, so the time it took for trees to grow also limited iron production.
- The amount of iron mined limited iron production.
- Smelting iron (separating out the nonmetallic elements in the iron ore) with charcoal could not supply enough iron to meet demand.
- Coal itself created too much smoke, so furnaces could not burn coal.
- Heating coal in an airtight oven produces coke. This process removes most of the smoke and sulfur compounds and makes it possible to use coal in the furnaces used to smelt iron.
- Smelting with coke was more efficient and much more economical than smelting with charcoal.
- Darby's furnace used coke as fuel rather than wood charcoal.
- Darby's furnace made possible the mass production of commercial-grade iron.
- Coal and iron were both in plentiful supply in England.
- Coke-smelting allowed impurities from the coal into the melted iron.
- Manufacturers complained that coke-smelted iron was brittle. They also said they could not work the coke-smelted iron easily.

A Few Facts

- The puddling furnace allowed the smelting, puddling, and rolling steps of processing iron to be combined into one operation that could be done near the coalfields. This saved time and money, as industrialists no longer had to transport heavy supplies to different factories.
- The puddling furnace separated out impurities and produced high-quality iron.
- Iron from a puddling furnace was strong, workable, and cost-effective.
- Cort's method of processing was the most successful for producing coke-smelted iron.
- With the puddling furnace, the British iron industry no longer depended on charcoal.

Newcomen's Steam Engine

Iron-maker Thomas Newcomen invented a **steam engine** that was used to pump water out of coal mines.



Newcomen's steam engine

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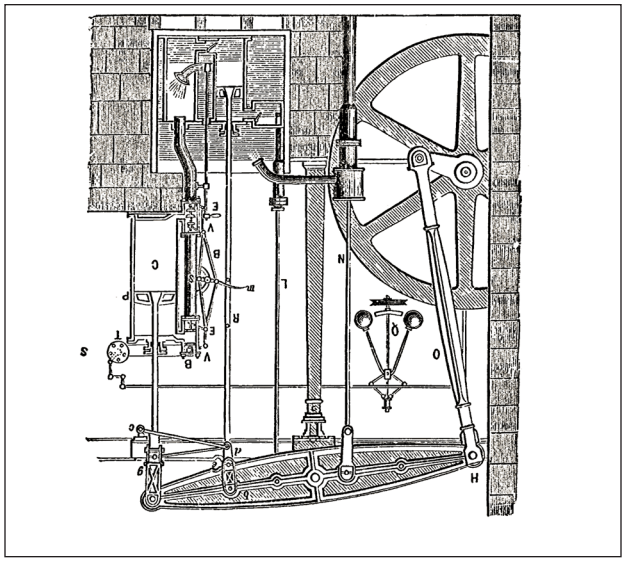
Watt's Steam Engine

Instrument-maker James Watt improved Newcomen's **steam engine** so it produced more power with less coal. Watt's engine eventually powered machines, boats, and trains.



Watt's steam engine

A Few Facts

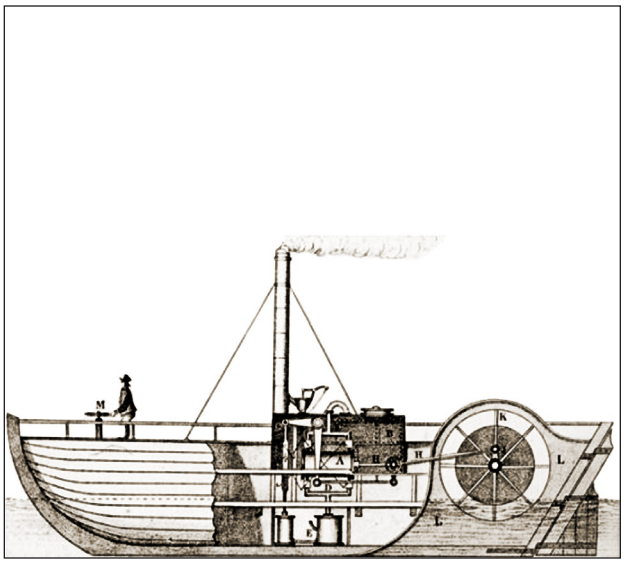
- As the demand for coal rose, coal supplies near the surface diminished. England's miners had to dig deeper and deeper to meet the demand for coal.
- Groundwater seeped into deeper mines, often covering the coal supplies and making the underground work difficult and dangerous.
- Horses originally provided the power to pump water out of the mines. The first steam engine did the work of a team of 500 horses.
- Newcomen and his partners built their first steam engine on top of a water-filled mineshaft. They used the engine to pump water from the mine.
- The steam engine worked by alternately heating and cooling water inside a cylinder to raise and lower a piston. This alternating cycle of evaporation and condensation created a regular up and down motion that mechanically operated a pump.
- Newcomen's steam engine was the first practical device to harness the power of steam and produce mechanical work.
- With the steam engine, for the first time, workers could pump water up from a depth of over 150 feet (45.7 meters).
- The Newcomen engine brought great benefits, but operating it consumed a great deal of coal.
- Because the steam engine used a lot of fuel, operating it was expensive.

A Few Facts

- When asked to repair a Newcomen steam engine, James Watt noted how inefficient it was.
- Watt improved on Newcomen's design so it produced more power with less coal.
- Watt's steam engine design used 75% less fuel than earlier versions of the engine.
- Watt's design replaced earlier steam engines in areas where coal was expensive.
- The efficient steam engine replaced wind and water as the most common source of power.
- The new steam engine went on to power machines in factories, boats, and eventually trains.
- Watt and his partner charged a "license fee" to engine owners based on the cost of the fuel they saved by using the new engine.

Symington's Steam Engine

Engineer William Symington conducted one of the first successful trials of a **steamboat**, a boat powered by a steam engine.



Early steamboat design

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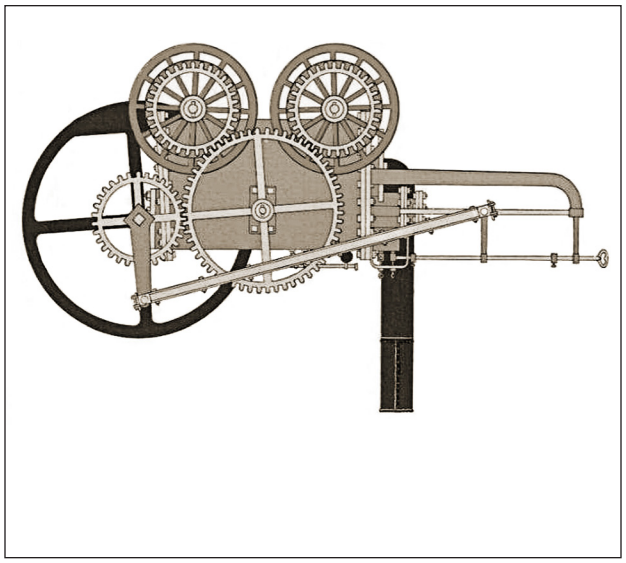
Trevithick's Steam Locomotive

Engineer Richard Trevithick mounted a steam engine he had reduced in size onto a carriage and ran it nearly 10 miles (16 kilometers) on iron rails, making the first **steam train locomotive**.



Design of first steam locomotive

A Few Facts

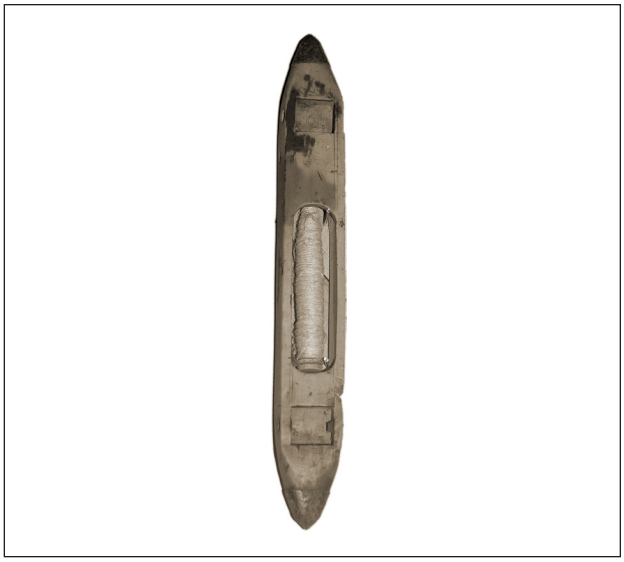
- Transporting goods and people on the water was sometimes a slow process. Moving against the current was difficult. Winds too calm to sail also created delays.
- Steamboats could move against the current regardless of the wind's direction or strength.
- People worried that putting a steam engine on a boat would cause a fire.
- Symington saw a way to capture the efficiency of the Watt engine and the simplicity of the Newcomen engine. He created an engine that would work on a boat without fear of the boat catching fire.

A Few Facts

- Horses provided labor to transport goods and people on land before and after steamboats were moving people and goods over water.
- Horse-drawn wagons moved with greater ease over wooden rails—wagonways—than over dirt roads.
- By 1776, iron had replaced the wood in the rails of wagonways and in the wheels on carts. Horses still provided the pulling power.
- An engineer could attach a smaller engine that could carry its own weight to a carriage. They could not do that with larger engines.
- Trevithick realized that the improvements to the steam engine's boiler technology could make it possible to produce and use high-pressure steam directly.
- A high-pressure steam engine allowed the use of a smaller cylinder, saving space and weight.
- The first locomotive, called "Puffing Devil," hauled 70 workers, 20 tons of iron, and five extra wagons over 9½ miles of track at 5 miles per hour—a record setting speed!
- Trevithick's locomotive used smooth wheels operating on smooth metal rails. Engineers had said achieving enough traction was impossible without using gear-like wheels on a slotted track.

Kay's Flying Shuttle

Toolmaker John Kay invented the **flying shuttle**, a tool that made it possible to weave cloth faster and in wider strips than when moving the shuttle by hand.



Flying shuttle

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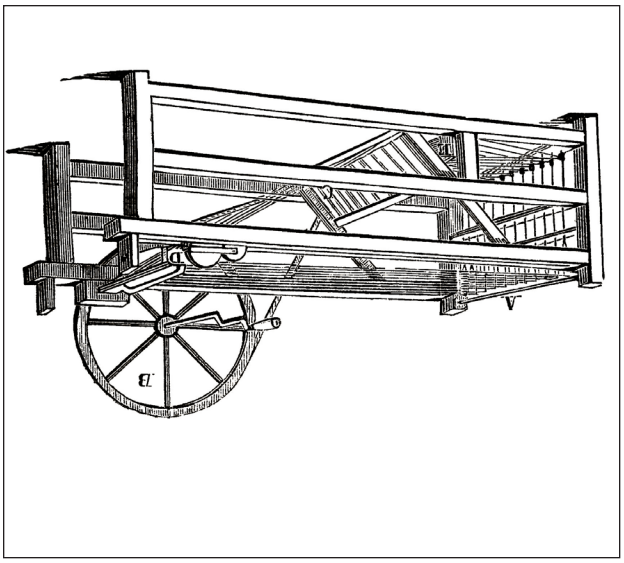
Spinning jenny



Hargreaves' Spinning Jenny

Carpenter and spinner James Hargreaves invented the **spinning jenny**, a hand-operated machine that allowed one person to spin eight threads of cotton at a time.

A Few Facts

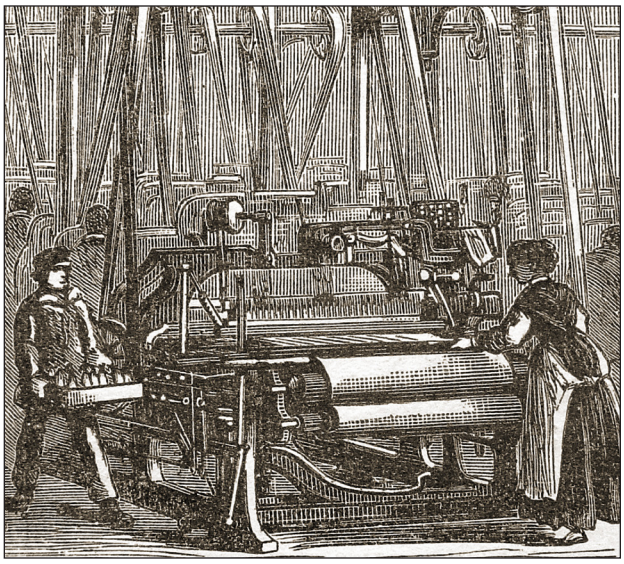
- England began to import cotton from its colonies; several British colonies became major producers of raw cotton.
- The demand for British textiles was rising throughout the world.
- Weaving cloth on a handloom required two hands. Thus, the reach of the weaver restricted the width of cloth woven. Operating larger looms required two weavers.
- The flying shuttle allowed the weaver to propel the shuttle through a wider strip of cloth using one hand. The other hand was free to perform the combing to compact the cloth.
- With the flying shuttle, one weaver could weave fabrics of any width more quickly than two workers could before.
- The textile industry was quick to adopt Kay's invention because it cut labor costs in half.
- The flying shuttle sped up the process of weaving on a handloom and increased production of cloth. This spurred the start of England's textile industry.
- With increased speed and production, the demand for yarn outstripped the available supply. Competition arose between weavers for the limited supply of yarn.

A Few Facts

- As the efficiency of the weaving process increased, manufacturers needed more cotton thread to keep up with production.
- It took three spinners to keep up with one weaver.
- Spinning wheels could spin one thread of cotton yarn at a time.
- The spinning jenny was a hand-operated machine that allowed one person to spin eight threads of cotton yarn at a time. It was the first machine to increase the efficiency of cotton yarn production significantly.
- The spinning jenny reduced the overall cost of producing cotton yarn.
- The spinning jenny could hold more than one ball of yarn, therefore making more cotton yarn in a shorter amount of time.
- The spinning jenny could meet the increased demand for cotton yarn that was created by the flying shuttle.
- Once the spinning jenny came into use, the price of yarn fell. The spinning community was angry about the drop in value.

Cartwright's Power Loom

Clergyman Edmund Cartwright patented a **power loom,** run by a watermill, that produced much more cloth than hand-operated looms.



Power loom

A Few Facts

- Power looms were mechanically operated versions of regular looms, an invention that combined threads to make cloth.
- With mechanized looms, weaving could keep up with spinning.
- At first, a watermill ran the power loom. Thus, textile makers had to build their workshops using power looms near a source of running water.
- Later, when the steam engine was improved, steam power was used to run the looms. Then textile makers could locate their workshops anywhere.
- As the efficiency of the power loom increased, women replaced most men as weavers in textile factories.
- By 1823, the claim was that a boy or girl, aged fourteen or fifteen, could manage two power looms and could produce three and a half times as much as the best handloom weaver.
- By 1850, there were 250,000 cotton power looms in Britain.
- Because of the complexity of the process, weaving was the last step in textile production to be mechanized.
- The power loom helped the textile industry respond to a radical increase in the volume and quality of yarns available to weavers.
- Power looms increased the speed and quality of weaving.